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The Dichotic Word Listening Test: Preliminary observations in American and Canadian samples

M A Roberts[1], M A Persinger[8], C Grote[2], L M Evertowski[1], J A Springer[3], T Tuten[4], D Moulden[8], K M Franzen[5], R J Roberts[6,1] & C S Baglio[7]

[1]University of Iowa, [2]Rush Presbyterian-St Luke's Medical Centre, [3]University of Cincinnati, [4]Culver-Stockton College [5]University of Northern Iowa, [6]Iowa City Department of Veterans Affairs Medical Center, [7]Louisiana State University, USA, [8]Laurentian University, Canada

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Abstract The present article describes observations of 670 American and Canadian child and adult control subjects on the recently developed Dichotic Word Listening Test (DWLT) The task was also administered to a sample of American children with traumatic brain injuries (n=21) of varying severity and a sample of American adults with mild traumatic injuries (n=36) The conceptual focus in this line of research was on using normative observations to identify clinically defective channels of auditory processing among patients The principal findings were as follows 1) the DWLT was sensitive to the effects of cerebral dysfunction following traumatic brain injury, 2) differences among normal samples with different demographic backgrounds were frequently observed, arguing for the development of local norms, 3) a shorter form of the DWLT task (DWLT30) can be used for screening purposes with relatively little reduction in sensitivity to cerebral dysfunction, 4) there appeared to be considerable improvement of DWLT performance between the ages of five and seven, due largely to higher scores from the left auditory channel, and 5) there were indications that use of French (rather than English) as one's native language before age six can negatively influence performance in adulthood on an English version of the DWLT In general, the present findings suggest that the DWLT is likely to have relatively broad applicability for neuropsychological assessment across the life-span

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CORRESPONDENCE Mary Ann Roberts, Hospital School, Department of Pediatrics, University of Iowa Hospitals and Clinics, Iowa City, IA 52242, USA

DICHOTIC listening is a well accepted experimental paradigm for studying human brain function in neuropsychology research laboratories (Springer 1986) However, practicing neuropsychologists do not typically employ dichotic listening tasks in routine clinical assessments In retrospect, it is somewhat surprising that clinicians have been relatively slow to embrace dichotic listening paradigms, given that impaired dichotic listening performances occur in a wide variety of patients with gross, structural, cerebral disease (Hugdahl, 1988) Defective dichotic listening performance has been observed experimentally and clinically with lesions in a variety of cortical loci (e g , Damasio & Damasio 1979), with discrete subcortical lesions (Cambier et al 1980, Castro-Caldas et al 1984), in brainstem disorders (Musiek 1983), in the context of aphasic syndromes (Bouma & Ansink 1988), in Parkinsonian patients (Springer et al 1991), with demyelinating disorders and other forms of white matter disease (Rao et al 1989), after damage to the corpus callosum (Risse et al 1989, Sidtis 1988), in patients with primary degenerative dementia (Mohr et al 1990), following organic solvent exposure (Varney et al 1991), as a long-term residual of severe febrile illness (Richardson et al 1989) and following closed head trauma (Levin et al 1989) In addition, a growing body of evidence suggests that dichotic listening performance may be sensitive to the presence of electrophysiological brain dysfunction in the *absence* of gross, structural lesions (Fincham et al 1979, Martzke et al 1990, Roberts et al 1990, Springer 1993)

There are several likely reasons why clinical neuropsychologists have failed to employ dichotic listening methodology for clinical purposes One potential explanation is that clinical audiologists, rather than neuropsychologists, have often developed dichotic stimulus materials for clinical assessment of central auditory processing Audiologists typically

utilize expensive equipment, such as sound-attenuated testing chambers, which most practicing neuropsychologists lack However, in early clinical field-trials with dischotic listening tapes, it became apparent to the authors that such tasks could be validly administered in a reasonably quiet environment with a good quality stereo cassette player A second factor impeding clinical acceptance of dichotic listening is that most dichotic listening tapes developed by experimental cognitive neuropsychologists are not commercially available, and thus many workable tapes have not been widely disseminated In addition, Williams (1989) has noted many tapes developed in research laboratories have a format which is too demanding or complex for routine use with dysfunctional patients Finally, much of the early experimental research with dichotic listening has focused upon demonstrating rather fragile hemispheric preferences for certain types of processing in normal subjects Because the goal of these experimental investigations was to demonstrate statistically significant (but not necessarily clinically relevant) ear assymmetries or ear advantages, the stimulus characteristics or response formats of the dichotic listening tapes employed were often purposely quite demanding in order to maximize the likelihood of finding positive results For example, in a study using a dichotic consonant-vowel task (i e , "ga" versus "ka" on a given trial) of a type often used to demonstrate left hemispheric superiority for processing verbal stimuli, the mean performance of a sample of neurologically healthy, 15-year-old subjects was 43% correct (Roeser et al 1983) Clearly, such a demanding task would be impractical for routine testing of many dysfunctional patients

In contrast to cerebral laterality research with normals, clinical studies with various neuropathological groups have focused *less* on fragile ear asymmetries and *more* upon documenting clear-cut, robust failures in auditory processing capacity due to cerebral disease Such clinically defective performances have been termed relative "extinctions" (e g , Damasio & Damasio 1979) or suppressions (Springer et al 1991) A relative extinction or unilateral suppression implies that the performance of one auditory channel in a given patient is clearly defective a) relative to the performance of that patient's contralateral channel, or b) relative to normative standards for healthy individuals of similar demographic background (as in the case of a bilateral suppression of both auditory channels in a given patient) In evaluating dichotic processing problems of central origin, it is assumed that the patient has adequate peripheral auditory acuity to perform the task This requirement can be demonstrated through brief testing with a pure-tone audiometer, by a clinical screening with the auditory portion of a routine sensory-perceptual exam, or by using a brief series of unilaterally presented practice items to demonstrate competence of monaural processing Ultimately, a formal audiological evaluation can be requested if the neuropsychologist has unresolved doubts concerning the possible impact of peripheral hearing problems upon dichotic listening performance in a particular case

It follows from the previous discussion that a relatively non-demanding dichotic listening paradigm which minimizes, rather than accentuates, the prominence of hemispheric preferences for processing different types of stimuli would be preferable for demonstrating suppression phenomena in clinical patients (cf , Springer et al 1991) To put it more pragmatically, when the clinician is interested primarily in testing for clearly dysfunctional channels of auditory processing due to brain disease, the naturally occurring hemospheric preferences (which are of such great interest to experimental laterality researchers) become "nuisance" factors (rather than phenomena of primary interest) which must be taken into account psychometrically when norming or standardizing one's task Thus, a task which proves useful for demonstrating clear auditory suppressions in clinical patients might be a relatively poor choice for eliciting a subtle right ear advantage (REA) or left ear advantage (LEA) for a certain type of processing in normal subjects, and vice versa

A simple dichotic listening task which has frequently been used to assess the presence of suppressions in clinical and experimental studies was developed in the Benton Laboratory of Neuropsychology at the University of Iowa and has been described in detail by Damasio & Damasio (1979) This tape has 110 dichotic trials in which a single, common, English word of one to three syllables in length is presented to the right channel while a different word of the same length is simultaneously presented to the left channel However, because presentation of all 110 trials is too time-consuming for inclusion in most clinical assessment protocols, a 50 trial short-form of this task was recently normed for neuropsychological assessment of adult patients (Richardson et al in press) Although use of this short-form in clinical research studies has produced replicable and coherent results (Gorman et al 1990, Roberts et al 1990, Verduyn et al 1992), there are several drawbacks to using this particular tape for clinical purposes For instance, the sound quality is less than optimal due to the presence of considerable "white noise" between trials Furthermore, an initial calibration tone is lacking The pre-trial prompt ("Now repeat ") is presented only to one ear and not

to both ears simultaneously, raising the possibility of a "priming" effect Also, use of the 50-item, short-form means that a limited number of word pairs are repeated Finally, some of the vocabulary items on selected trials are somewhat difficult for younger children, limiting the tape's applicability to elementary school populations

The goal of the present investigation was to develop and standardize a dichotic listening tape which would be suitable for use in clinical assessments with child, adolescent, and adult populations The resulting task, the DWLT (Auditec of St Louis 1991), which draws heavily upon the format of the dichotic listening tape developed in the Benton Laboratory of Neuropsychology, was designed to circumvent many of the drawbacks described above Normative observations for children, adolescents, and younger adults, from both the United States and Canada will be presented, along with preliminary clinical observations from American samples of children and young adults who have sustained mild-to-moderately severe head trauma Data based upon the full 60 item DWLT and a 30-item shorter form (DWLT30) will be presented

General procedure

Task description

The standard form of the DWLT (Auditec of St Louis 1991) consists of 20 monaural practice trials (in which a single word is presented to either the right or left auditory channel), followed by 60 dichotic test trials (in which two words with the same number of syllables are simultaneously presented to the right and left auditory channels) Prior to the monaural test trials, there is a calibration tone For individuals with relatively intact hearing, the volume knob on the cassette player can be adjusted so that the calibration tone is roughly at 75 db peak equivalent sound pressure level All DWLT stimuli are common English words varying in length from one to three syllables These words have been drawn from elementary school reading lists and are generally within the working vocabulary of most normal fourth-graders Prior to presentation of the target stimuli for either monaural or dichotic trials, the prompt "Now repeat " is presented to both ears

The DWLT was constructed so that the first 30 dichotic test trials could serve as a shorter form of the 60-item task, and dichotic items 31–60 could function as an alternate short form if a repeated assessment was needed Within the first block of 30 dichotic trials, the stimulus words presented to the right and left channels have been equated for frequency of usage in American English (Kucera & Francis 1967) This was also done for the second block of 30 dichotic test trials Furthermore, there were no significant differences in frequency of usage between words presented to the right and left channels during the first block of 30 trials and those presented to the respective channels during the second block of 30 trials With regard to phonetic characteristics of the stimulus words, an effort was made within each 30-trial block of dichotic test trials to counterbalance the qualitative aspects of the initial consonant sounds of each word in a pair For example, if in a given trial a word beginning with a plosive consonant was presented to the right ear in conjunction with a word beginning with a sibilant which was presented to the left ear, then a pair was included later within the same trial block where a word starting with a sibilant was presented to the right ear in conjunction with a plosive-initiated word to the left ear This counterbalancing of phonetic characteristics also characterized the second block of 30 dichotic trials as well

For both the 60-item standard form and the 30-item shorter form (DWLT30), three scores are typically employed to assess adequacy of performance 1) the number of correct responses from the right channel (#R), 2) the number of correct responses from the left channel (#L), and 3) the number of trials on which both stimuli in a dichotic pair were correctly reported (#B) In addition, the Laterality Index (LI), $(\#R-\#L/\#R+\#L)\times 100$, was also calculated

Task administration

For all normal volunteer subjects and clinical patients, the DWLT was administered according to the standard instructions given in the manual (Auditec of St Louis 1991) The volume knob on the cassette tape player was adjusted so that the calibration tone was initially set at 75 pb peak sound pressure level (SPL) prior to an individual administration Minor adjustments to volume were permitted for individual comfort during practice trials to permit patients to perform optimally All subjects included in the various samples denied the presence of clinically significant hearing loss The majority of subjects in various normative samples had their auditory acuity tested using pure-tone audiometry In some samples, the acuity of the majority of subjects was tested using a brief version of routine sensory-perceptual screening For clinical patients, the DWLT was usually administered as part of a 1 5 to 3 0 h test battery For volunteer subjects in some samples, the DWLT was administered in conjunction with 15 to 45 min of other unrelated cognitive tasks or self-rating scales All investigators involved complied with the required procedures at their re-

spective institutions for obtaining informed consent and debriefing research participants

Investigation 1 child and adolescent observations

American samples

Rural normal (RN) sample – Research participants in this sample were kindergartners (n=24), second graders (n=19), fourth graders (n=31), and sixth graders (n=20) from a small midwestern town All subjects had volunteered with the written consent of their parents The sample was almost entirely Caucasian The mean ages of the various grade subsamples were as follows kindergarten, mean age=72 5 months (SD=3 3, range 66–79), second grade, mean age=96 2 months (SD=5 0, range 89–105), fourth grade, mean age=118 7 months (SD=4 1, range 109–127), and sixth grade, mean age=141 7 months (SD=4 1, range 135–146) The mean PPVT-R IQ of the sample combined across all grades was in the average range of functioning (M=102, SD=12)

Ancillary normal (AN) sample – For reasons to be described below, data on a supplementary normal sample of first graders (n=20) and second graders (n=28) was collected following preliminary analyses of the RN sample data Research participants in the sample were Caucasian children residing in a small midwestern city The mean age of the first graders was 87 3 months (SD=3 8, range 82–95), and the mean age of the second graders was 100 0 months (SD=4 3, range, 92–107) The mean PPVT-R IQ of the sample was at the upper end of the average range of functioning (m=109, SD=14)

Pediatric brain injury (PBI) sample – This clinical sample consisted of 21 children (14 males, 7 females) referred for neurobehavioral evaluation following a traumatic brain injury The demographics of the sample were as follows age, M=8 6 (SD=1 5, range 6–11), prorated WISC-R IQ, M=91 6 (SD=21 6, range 40–128), number of months intervening between injury and assessment, M=26 4 (SD=13 4, range 6–59) According to criteria used by Levin et al (Levin et al 1987), 13 of the subjects were judged to have sustained a severe brain injury and the remaining 8 patients suffered mild brain trauma

Results

Lack of gender effects

Preliminary analysis indicated a lack of significant gender effects for the American and Canadian samples Accordingly, data from subjects of both genders were combined in all subsequent analyses

RN sample

Summary statistics for dichotic listening data in the various grade sub-groups comprising the RN sample are presented in Table 1 Tenth percentile cutoff scores are also presented for the entire DWLT and the abbreviated DWLT30

Analyses of variance confirmed the presence of significant effects of school grade on all four DWLT dichotic indices (i e , #L, #R, #B, and LI) with all p-values <0 0001 For the entire RN sample, the correlations between age and DWLT indices were as follows #L, r=0 61, p<0 01, #R, r=0 39, p<0 01, #B, r=0 66, p<0 01, LI, r=0 21, p<0 05 Inspection of Table 1 reveals that for the kindergarten sub-group (mean age= 5 6 years) the 60 item DWLT was most likely too demanding a task for routine clinical use with children in this age range However, the dichotic listening performance of second graders (mean age=7 5 years) was sufficiently robust to permit establishment of meaningful tenth percentile cutoff scores In general, there was consistent improvement with age on all dichotic indices over the four age groups, with the exception of relatively little change in #R performance between the fourth and sixth grade sub-groups, this findings contributes to the differential sizes of the correlations of age with the #L and #R scores described above As can be seen in Table 1, the size of the discrepancy between mean #L and mean #R performances progressively diminished after kindergarten This pattern of results indicates that the right ear advantage (REA) for processing verbal stimuli is already well-developed in kindergartners Thus, improved dichotic performance in this age-range largely reflects that growing capability in the left auditory channel to process information when the right channel is occupied by similar processing demands In contrast to the progressive improvement in the #B index with age, processing of monaural practice trials improved significantly between kindergarten (mean #MB=16 2, SD=1 1) and second grade (mean #MB=18 6, SD= 1 0), but not thereafter, with mean fourth grade (mean #MB=18 4, SD=1 3) and sixth grade performance (mean #MB=18 2, SD=1 3) being virtually identical with that of the second graders

Relationship with IQ – #L, #R, and #B scores were significantly correlated with PPVT-R IQ r=0 40, 0 43, and 0 46, respectively (p<0 001 in each case) Thus, dichotic processing capacity was moderately correlated with a measure of verbal intellectual functioning in this age range

Correlation between the DWLT and DWLT30 – Correlations between the full DWLT and the DWLT30 short-form were routinely robust in the RN sample For example, correlations between the two forms for

TABLE 1 Descriptive statistics for DWLT and DWLT30 performance in American child samples

Grade		DWLT				DWLT30			
		#L	#R	#B	LI	#L	#R	#B	LI
		Rural normal sample							
K	Mean	23 8	41 3	15 5	29 6	12 3	20 4	7 3	26 0
	SD	9 8	9 2	9 6	29 8	4 8	4 9	5 1	25 0
	Range	4–39	9–53	0–32	−60–+85	3–20	5–26	0–17	−56–+74
	10th %ile	5 0	30 0	2 0	–	5 0	15 0	0 0	–
2	Mean	41 7	47 2	33 5	5 9	21 1	23 0	16 6	4 2
	SD	9 4	9 2	10 9	19 0	3 8	4 7	4 8	17 2
	Range	13–54	16–55	8–47	−41–+59	9–26	10–27	6–23	−33–+49
	10th %ile	31 0	32 0	21 0	–	17 0	19 0	10 0	–
4	Mean	49 3	53 7	44 7	4 0	23 8	26 8	21 6	6 9
	SD	7 5	2 7	7 6	8 2	4 3	1 6	4 2	9 7
	Range	23–58	43–57	21–54	−7–+39	10–29	22–30	9–28	−6–+46
	10th %ile	41 0	49 0	37 0	–	17 0	24 0	15 0	–
6	Mean	53 0	54 2	48 6	1 2	26 0	27 1	23 8	2 2
	SD	3 3	2 6	3 7	3 9	2 2	1 6	2 3	5 4
	Range	47–59	46–57	39–55	−5 5–+7 8	21–30	24–30	20–28	−7–+13
	10th %ile	48 0	50 0	45 0	–	23 0	24 0	20 0	–
		Ancillary normal sample							
1	Mean	–	–	–	–	16 7	21 0	11 7	9 0
	SD	–	–	–	–	5 3	5 9	6 7	24 0
	Range	–	–	–	–	6–28	4–28	0–27	+68–+57
	10th %ile	–	–	–	–	10 0	17 0	4 0	–
2	Mean	–	–	–	–	22 4	24 0	18 1	4 7
	SD	–	–	–	–	4 5	2 8	4 5	10 6
	Range	–	–	–	–	15–28	18–29	12–25	−15–+24
	10th %ile	–	–	–	–	15 0	19 0	12 0	–

the #B score across all four grades were as follows kindergarten, r=0 86, second grade, r=0 94, fourth grade, r=0 97, sixth grade, r=0 82 Correlations of similar magnitude were also observed for the #L, #R, and LI dichotic indices

AN sample

Descriptive statistics for DWLT30 data for first and second graders are presented in Table 1 Comparison of the second graders from this sample with RN second graders indicates that the levels of performance were highly similar in the two second grade subgroups

Multiple t-tests comparing first and second graders from the AN sample demonstrated significant differences between these two age groups on the #L30, #R30, and #B30 scores (all p-values <0 01), but there was no significant difference between groups on the LI30 score (t_{46}=0 85, ns) Considered together, the data in Table 1 suggest (a) that there is considerable maturation of dichotic processing capacity between the ages of 5 and 8 years, and (b) that, by mid-first grade, one can probably begin to draw reasonably solid inferences about grossly defective performance (e g a 7-year-old child who fails to produce a single trial on which both words are correctly reported is performing in an impaired or, at least, developmentally delayed fashion) Comparison of DWLT30 data from the RN kindergarten sample with that from the AN first-graders suggested that maturation of left channel processing capacity between the ages of 5 and 7 accounts for the bulk of the improvement in #B performance

In summary, findings from the AN sample (a) confirmed occurrence of substantial development of left channel processing in first graders which was suggested by results from the RN sample, and (b) suggested that some preliminary clinical inferences regarding adequacy of DWLT performance can be drawn between the ages of 6 and 7

PBI clinical sample

Of the 21 brain-injured children in the PBI sample, 9 (43%) obtained a #B30 score which was below the 10th percentile of the appropriate age-reference group Among those 9 PBI children who performed defectively, 7/9 had severe brain injuries and two were classified as mild It is worth re-emphasizing that the average length of time between injury and testing was substantial, thus, impaired dichotic performance would appear to be a static or at least a longer term deficit in those patients who failed the task Although

the mean IQ of the children who failed the DWLT30 task (M=84 1, SD=21 6) was 15 7 IQ points poorer than those who performed above the tenth percentile (M=99 8, SD=19 4), two subjects who failed had WISC-R IQ scores of 113 and 117 Thus, poor dichotic listening performance among brain-injured children was not necessarily associated with generalized intellectual deterioration

Canadian sample

Canadian school-age (CS) sample – Research participants in the CS sample were first through twelfth graders who resided in a small city in a central Canadian province All subjects were volunteers whose parents had given their informed consent in writing Roughly equal numbers of males and females were tested at each grade level A minority of subjects came from bilingual households where French was their native language (i e , first lanuage acquired in childhood) Similar to previous samples, this sample was almost entirely Caucasian

Results

Age/grade effects – Descriptive statistics for the Canadian child and adolescent sample on the DWLT are presented in Table 2 Visual inspection of the table reveals relatively consistent and linear improvement in mean #B performance until 8th grade, at which time performance tends to reach asymptote The lone exception to this was the mean #B performance of sixth graders which was slightly but not significantly below that of the fifth grade sub-group, due possibly to random variation

Analyses of variances revealed a significant main effect for grade-level, and indicated a developmental trend for all four dichotic listening indices of interest #L, #R, #B (all p-values <0 0001) and LI (p=0 05) Consistent with findings described above for the American AN sample, there was a substantial improvement in mean #B performance from first grade to second in the CS sample Across the entire CS sample (n=238), the correlations between age and DWLT scores (#L, #R, & #B respectively) were as follows 0 38, 0 42, and 0 44 (p<0 001 in each case)

Comparison of CS and RN grade sub-groups – Inspection of Tables 1 and 2 demonstrates that American second, fourth, and sixth graders appeared to be performing somewhat better than their Canadian counterparts on the #B index Formal statistical analyses comparing CS and RN second graders revealed only a single significant difference on mean #R score (t_{42}=−2 06, p=0 04), mean difference on #L, #B, and LI indices failed to reach significance Among fourth graders, mean performances on #L (p=0 02), #R (p= 0 0001), and #B (p=0 0007) were all significantly higher in the RN sample relative to the corresponding mean performances in the CS sample, only mean LI failed to differentiate American and Canadian fourth graders A parallel set of findings characterized the differences between American and Canadian sixth graders

In summary, between the ages of 8 and 9, statistically significant differences between normal American and Canadian elementary-aged children were found These differences were substantial enough to discourage clinicians from simply appropriating norms derived from one English-speaking child sample and applying them in another English-speaking child population Although this investigation was not designed to determine the variables responsible for the observed differences between American and Canadian children, it seems likely that the accent and articulation of the American narrator on the DWLT tape or the presence of bilingualism in some Canadian homes were likely to be factors which influenced the obtained results

Investigation 2 young adult and adult observations

American samples

Midwestern university (MU) sample – Research participants were 60 undergraduates enrolled in introductory psychology courses at a large, midwestern state university Subjects gave their informed consent to participate while completing part of a course requirement The demographics of this young adult sample were as follows mean age=19 1 (SD=1 5, range 18–27), means years of education=12 7 (SD=0 8, range 12–15), 35 females, 25 males The sample was almost entirely Caucasian All subjects denied history of closed head injury and severe febrile illness in adulthood

Brain injured (BI) sample – This clinical sample consisted of 36 young adult patients who were consecutively referred to one of two neuropsychologists for evaluation of cognitive functioning following traumatic brain injuries, most often sustained in motor vehicle accidents The demographics of the sample were as follows mean age=19 1 (SD=3 6, range 16–28), mean years of education=11 0 (SD=1 6, range 8–14), 22 females, 14 males This sample was entirely Caucasian The mean prorated WAIS IQ of this young adult sample was 101 (SD=10, range 84–121), which is clearly in the average range of general intellectual functioning (i e , the majority of patients did not manifest generalized cognitive impairment) The ma-

TABLE 2 Descriptive statistics for DWLT performance in the Canadian school-age (CS) sample

Grade	#L	#R	#B	LI	Grade	#L	#R	#B	LI
1 (*n*=32)					7 (*n*=25)				
Mean	30 9	36 9	19 3	7 7		50 2	49 9	43 0	−0 2
SD	13 7	10 1	11 1	32 6		5 2	5 4	7 6	6 2
Range	3–58	7–55	2–53	−59–+88		35–57	38–57	30–53	−11–+21
10th %ile	10	22	3	–		42	42	31	–
2 (*n*=25)					8 (*n*=16)				
Mean	38 8	40 9	28 4	3 4		52 7	52 3	47 0	0 0
SD	11 3	10 7	11 5	10 9		4 3	5 0	6 0	5 1
Range	11–53	10–53	1–45	−45–+49		43–60	40–59	36–59	−17–+6
10th %ile	20	24	11	–		43	44	37	–
3 (*n*=30)					9 (*n*=21)				
Mean	41 1	47 0	33 0	6 8		53 7	51 7	47 1	−2 0
SD	7 1	7 0	9 1	9 8		4 4	5 4	7 0	4 8
Range	28–53	28–58	11–49	−15–+27		39–60	37–59	32–59	−13–+10
10th %ile	30	37	22	–		43	45	37	–
4 (*n*=13)					10 (*n*=19)				
Mean	43 0	48 0	35 4	6 5		53 1	52 9	47 4	0 2
SD	9 2	2 9	8 1	11 0		4 8	2 6	5 4	4 1
Range	30–56	42–53	24–49	−11–+22		43–59	46–57	35–55	−6–+10
10th %ile	31	40	25	–		43	46	38	–
5 (*n*=20)					11 (*n*=10)				
Mean	50 7	47 7	41 1	−3 6		54 3	53 9	49 3	−0 4
SD	4 4	6 3	6 6	6 7		2 6	2 5	4 1	1 5
Range	41–58	35–56	28–54	−17–+9		51–58	50–57	44–54	−3–+1
10th %ile	38	41	28	–		47	47	40	–
6 (*n*=17)					12 (*n*=10)				
Mean	47 6	46 2	38 1	−2 2		52 7	51 7	46 8	−1 0
SD	7 6	8 1	10 7	10 5		3 6	4 0	5 3	4 7
Range	28–55	28–55	14–50	−18–+22		44–58	45–57	40–55	−8–+8
10th %ile	38	41	28	–		47	47	40	–

jority of patients in this sample suffered relatively mild head trauma Those patients who had received Glasgow Coma Scale ratings had scores that ranged from 13 to 15

Rural adult (RA) sample – This sample consisted of 76 adult volunteers from two small, midwestern cities surrounded by rural areas Many of the individuals in this sample were hospital employee volunteers Sample demographics were as follows mean age= 34 1 (*SD*=12 1, range 16–67), mean years of education=14 0 (*SD*=1 9, range 10–16), 42 females, 34 males The sample was largely Caucasian, and all subjects denied history of closed head injury and severe febrile illness in adulthood

Urban adult (UA) sample – This sample consisted of 48 adult volunteers from a major, midwestern, metropolitan area, the majority of whom were hospital employees The demographics of this urban adult sample were as follows mean age=34 6 (*SD*=11 4, range 19–64), mean years of education=13 5 (*SD*=1 6, range 10–16), 34 females, 14 males, 38 Afro-Americans, 10 Caucasian Americans The mean PPVT-R IQ of this sample was 93 (*SD*=20, range 67–143)

Results

Absence of gender effects

Because preliminary analyses failed to reveal any significant gender effects in the American young adult samples, observations from males and females were pooled in subsequent analyses

Midwestern university (MU) sample

Descriptive statistics – Descriptive statistics for DWLT and DWLT30 performance data are presented in Table 3 For the MU sample, the DWLT had an extremely high ceiling, with mean performance for both left and right channels falling at roughly 95% efficiency, and mean performance on the #B index reflecting 92 5% efficiency Thus, for young adults the DWLT was a relatively non-demanding task with a broad range of scores for capturing severely defective performances

In order to assess the relative equivalency of trials 1–30 and trials 31–60, multiple paired *t*-tests were performed, and these failed to demonstrate any significant differences on any of the dichotic listening indices between the two trial blocks The respective mean

TABLE 3 *Descriptive statistics for DWLT and DWLT30 performance in adult American and Canadian samples*

Sample		DWLT				DWLT30			
		#L	#R	#B	LI	#L	#R	#B	LI
Midwest university (MU)	Mean	57 2	57 9	55 5	0 6	28 5	28 8	27 5	0 9
	SD	1 7	1 7	2 6	1 7	1 0	1 2	1 7	2 1
	Range	54–60	52–60	49–60	−3–+5	27–30	25–30	23–30	−5–+5
	10th %ile	54	55	52	–	26	27	25	–
	5th %ile	53	54	50	–	26	26	24	–
Brain injured (BI)	Mean	52 1	54 1	48 5	2 6	25 9	27 4	24 2	3 0
	SD	9 1	7 5	10 7	6 1	4 1	3 6	5 2	7 2
	Range	9–60	16–60	0–60	−6–+28	7–30	9–30	0–30	−7–+26
	10th %ile	–	–	–	–	–	–	–	–
	5th %ile	–	–	–	–	–	–	–	–
Rural adult (RA)	Mean	55 8	57 2	53 6	1 1	27 8	28 5	26 5	1 3
	SD	3 6	3 1	4 9	2 9	2 0	1 8	3 1	3 4
	Range	37–60	44–60	25–60	−7–+9	18–30	20–30	10–30	−9–+9
	10th %ile	51	54	49	–	25	26	24	–
	5th %ile	49	51	46	–	24	25	23	–
Urban adult (UA)	Mean	53 5	54 8	50 0	1 1	–	–	–	–
	SD	5 0	4 2	6 5	3 7	–	–	–	–
	Range	38–60	41–60	34–59	−5–+13	–	–	–	–
	10th %ile	46	49	39	–	–	–	–	–
	5th %ile	41	45	36	–	–	–	–	–
Canadian university (CU)	Mean	51 3	53 9	47 1	2 8	–	–	–	–
	SD	7 4	5 1	9 4	7 3	–	–	–	–
	Range	20–60	36–60	17–58	−6–+46	–	–	–	–
	10th %ile	43	46	34	–	–	–	–	–
	5th %ile	40	44	26	–	–	–	–	–

scores for the first and second 30-trial blocks were as follows #L, 28 5 vs 28 6, #R, 28.8 vs 29.0, #B, 27.5 vs. 28 0 In general, the data suggested that the efforts to balance the first and second halves of the DWLT on salient stimulus characteristics were relatively successful

In order to investigate the effects of the varying lenght of DWLT stimulus words on performance, multiple *t*-tests were performed on MU sample data The results of these analyses can be summarized as follows 1) single-syllable words were significantly more difficult than two or three-syllable words on all dichotic indices (i e , #L, #R, and #B, all *p*-values <0 001), 2) two-syllable words were significantly more difficult than three-syllable words for #L and #B indices ($p<0$ 003 in both cases), but there was no significant difference between two syllable and three syllable words on the #R score ($t_{59}=-1$ 43, ns)

Brain injury (BI) sample

Descriptive statistics – Descriptive statistics for DWLT performance in the BI sample are presented in Table 3 A *t*-test indicated that there was no significant difference in age between the clinical BI sample and the MU comparison sample The mean DWLT performances of the BI sample were significantly poorer than those of the MU sample on all dichotic indices #L ($t_{35}=3$ 41, $p<0$ 002), #R ($t_{35}=3$ 16, $p<0$ 01), #B ($t_{35}=4$ 16, $p<0$ 003)

With regard to the performances of individual patients in the BI sample, 13/36 (36%) patients performed at or below the 5th percentile of the MU sample on #L, 14/36 (39%) performed defectively on #R, and 19/36 (53%) performed in the impaired range on #B The percentage of BI patients failing any one dichotic index was 53% (19/36), the same percentage as failed the #B index

With regard to performance on the DWLT30 shorter form of the task, the failure rates for the BI sample were as follows #L, 13/36 (36%), #R, 10/36 (28%), #B, 13/36 (36%) Overall, 18/36 (50%) of BI patients performed defectively on at least one DWLT index Thus, if one considers a failing performance on any one of the three major dichotic indices as impaired performance, the overall hit-rate for defective performance (less than 5th percentile) on the DWLT30 (i e , 50%) was comparable with that of the entire DWLT task (i e 53%) This finding suggests that the shorter form of the task can be used for screening purposes with relatively little loss in sensitivity to cerebral dysfunction

Rural adult (RA) sample

Absence of gender effects – Because there were no significant gender effects in the RA sample, data from

males and females were pooled in the following analyses

Age effects – Descriptive statistics for DWLT performance on the RA sample are presented in Table 3 Although the #R performance of the older RA sample did not differ significantly from that of the younger MU sample, mean #L and #B performances among RA subjects were significantly lower than for MU subjects #L (t_{59}=2 83, p<0 01), #B (t_{59}=2 58, p<0 02) Similarly, the recommended 5th percentile cutoffs for the RA sample were somewhat lower than those for the MU sample

DWLT30 performance – As was observed in the younger MU sample, the correlation between DWLT30 and DWLT performance in the RA sample were quite substantial #L, r=0 91, #R, r=0 89, #B, r= 0 91

Urban adult (UA) sample

Descriptive statistics for DWLT performance in the UA sample are presented in Table 3 There were no significant gender effects in this sample Inspection of group means and 5th percentile cutoffs in Table 3 indicates that UA sample performances were somewhat lower than those of the RA sample, particularly at the lower end of the distribution, despite the fact that the two samples did not differ significantly in mean age Multiple t-tests confirmed that mean UA performances on the DWLT indices were significantly below those of the RA sample #L, (t_{122}=−3 24, p<0 002), #R (t_{122}=−3 44, p<0 001), #B, (t_{122}=−3 51, p<0 0001) Thus, the findings suggest that clinicians would do well to consider developing local norms, rather than assuming that performance standards based on rural samples are routinely appropriate for evaluating the performances of urban residents, and vice-versa

Canadian sample

Canadian university (CU) sample – Research participants were 100 undergraduates enrolled in introductory psychology courses at a central Canadian university The demographics of this Canadian young adult sample were as follows mean age=19 3 (SD=0 9, range 18–23), mean years of education=14 2 (SD=0 8, range 13–16), 55 females, 45 males Similar to the American samples, the CU sample was almost entirely Caucasian

Results

Comparison with American MU sample – Descriptive statistics for the CU sample are presented in Table 3 There was no significant effect of gender in this sample As observed for elementary aged children, the young adult CU sample performed significantly below the American MU sample on all three DWLT indices #L, (t_{158}=6 10, p<0 0001), #R, (t_{158}=5 82, p<0 0001), #B, (t_{158}=6 78, p<0 0001) Furthermore, the 5th percentile cutoffs for the Canadian sample were substantially below those obtained from the MU sample

To assess whether the observed differences in DWLT performance between the CU and MU samples could be attributed to an overall higher level of general cognitive ability in the MU subjects, a *post hoc* comparison sample composed of American students from a less academically competitive, midwestern college (MC sample, n=38) was drawn The rationale for doing so was that the level of general intellectual functioning for the MC sample more closely approximated that of the student body from which the CU sample was drawn However, the mean performance level of the MC sample closely resembled those found in the MU sample, and the results of multiple t-tests indicated that the MC sample performed significantly better than the CU sample on all dichotic indices #L, (t_{136}=−4 92, p<0 001), #R, (t_{136}=−2 15, p<0 04), #B, (t_{136}=−4 23, p<0 001) Thus, it seemed unlikely that a difference in general academic or cognitive ability could be invoked to explain the substantial performance differences between the CU and MU samples

Another possible explanation for the observed performance differences between the young adult samples from Canada and the midwestern United States was that the MU sample was explicitly screened for history of head trauma, whereas history of mild head trauma was not an explicit exclusionary criterion for the CU sample However, *post hoc* analysis among CU subjects failed to reveal any significant differences in DWLT performance between those CU subjects who reported positive histories for mild head trauma and those who did not

As discussed above, another potential factor which could be invoked to account for performance differences between Canadian and American samples is the presence of bilingualism in a number of Canadian families For purposes unrelated to the present investigation, data on the status of native language was collected for 68 of the 100 subjects in the CU sample The mean #B performance for CU subjects from monolingual homes where English was the native language was 50 2 (SD=4 6, n=55), whereas mean #B performance for CU subjects from bilingual homes where French was the native language was 45 2 (SD= 6 1, n=13) This difference was statistically significant ($F_{1\,66}$=10 10, p<0 01) A comparable result was obtained for the #R score ($F_{1\,66}$=9 57, p<0 01), while the findings for #L failed to reach significance ($F_{1\,66}$=3 84,

$p=0.06$) Thus, there was some support for the notion that use of a different language (i.e., French) before age six can exert a significant influence on dichotic word listening performance in adulthood if the dichotic stimuli came from the second language acquired However, it should also be noted that the mean #B score of the 55 monolingual, English speakers in the CU sample still did not approach the mean #B performance of the MU sample from the United States Thus, other factors must also influence discrepancies in performance between Canadian and American samples

Discussion

Overview

The findings from the present study suggest that it is likely that the DWLT will have relatively broad applicability across the life-span Observations from clinical pediatric and young adult samples indicate that the DWLT task is sensitive to the effects of cerebral dysfunction following traumatic brain injury DWLT performance from rural, midwestern, adult American samples was significantly better than performance in an urban American sample, and the performances of American samples were generally superior to those of age-matched Canadian samples Thus, the findings argue for the development of so-called "local norms" by clinicians who serve patient populations with demographic characteristics which differ from those of the populations studied in this investigation When compared to the results obtained when the entire DWLT was administered, preliminary findings with shorter DWLT30 suggest that it can be used for screening purposes with relatively little reduction in sensitivity

DWLT performance and traumatic brain injury

In a separate study, Richardson et al (Richardson et al in press) observed that 36% of a randomly selected sample of 50 brain-injured adults performed defectively on at least one dichotic listening index when assessed with a dichotic listening task with a format which is highly similar to that of the DWLT (cf., Damasio & Damasio 1979) The observed failure rates of 50% for the DWLT30 in the adult BI sample and 43% in the younger PBI sample compare favorably with the findings from Richardson's study The findings from the PBI sample are consistent with previous research indicating that children and adolescents can sustain persistent deficits in central auditory processing following traumatic brain injury (Cockrell & Gregory 1992)

With regard to the mechanisms underlying dichotic listening failure following cerebral trauma, what appears to be emerging from the clinical literature is the view that there are likely to be multiple factors which can impair dichotic performance Clearly, if a given patient sustains a gross, structural lesion in the primary auditory pathways, defective performance can be attributed to the primary effects of a focal lesion (Damasio & Damasio 1979) Additionally, Levin and colleagues have called attention to the role of smaller, multifocal, lesions in white matter in producing marked asymmetries in dichotic listening performance following traumatic brain injury (Levin et al 1989) Finally, clinically significant dichotic listening failures have been observed following closed head injuries in patients who reported multiple partial seizure-like symptoms in the absence of identified gross structural lesions by CT or MRI (Roberts et al 1990, Verduyn et al 1992, Richardson in press) These observations raise the possibility that subclinical electrophysiologic dysfunction may produce or contribute to dichotic listening impairments following closed head injury

Generalizability of results from different samples

Unexpectedly, relatively consistent and sizable mean performance differences were observed between age-matched American and Canadian samples In particular, blind application of performance standards based on rural, midwestern, American subjects would have resulted in a number of presumably normal Canadian children and adults being regarded as "false-positives" *Post hoc* analyses suggested that the acquisition of Frensh as the native language was one factor which contributed to differences in performance levels between samples from the two countries Obrzut et al (1988) reported similar findings from an investigation that included a sample of bilingual children with native languages other than English In this investigation, a group of bilingual children ($n=15$), ranging in age from 6 to 13 years, performed lower on a *consonant-vowel-consonant* (CVC) dichotic listening condition (i.e., beb/deb/keb/geb) than comparison groups Further, the native languages of these children were Spanish ($n=8$), Portuguese ($n=3$), Vietnamese ($n=2$), Chinese ($n=1$), and Greek ($n=1$) Thus, the present study has extended these previous findings to children and young adults whose first acquired language was French Given that two dichotic listening tasks with different formats were used, this increases the generalizability of these findings

To a lesser extent, the urban-dwelling American UA sample performed relatively poor compared to the RA

sample The specific factors underlying the mean differences between the RA and UA remain to be elucidated, however, differences in socioeconomic status have previously been found to exert systematic effects on other types of dichotic listening tasks (e g , Borowy & Goebel 1976) In summary, the present data suggest that clinicians should strongly consider developing local norms to avoid drawing erroneous conclusions when the patient populations served have demographic characteristics which differ markedly from the various samples studied in this investigation

Developmental issues

Findings from the present study suggest that DWLT performance is stable enough by second grade to permit clinicians to identify clearly impaired performance on a case-by-case basis Both American and Canadian child samples demonstrated substantial maturation of performance due largely to marked improvement in the left channel performance between the ages of 5 and 7 Various factors which have been invoked to account for improved performance in this age-range include physical maturation of the brain, the development and use of different strategies for performing dichotic listening tasks, and the overall difficulty or response format of the task employed (Hiscock & Dector 1988) Findings from the Canadian sample (CS) suggested that performance begins to reach asymptote around 8th and 9th grade with relatively little additional change through young adulthood Thus, DWLT performance appears to plateau in mid-adolescence even though the corpus callosum apparently continues to mature well into the third decade (Pujol et al 1993) Whether performance on a more demanding dichotic listening task would reach asymptote later in development is not known

For American college-age subjects in the MU sample, the DWLT was a relatively easy task to perform Comparison of the present norms for the DWLT with MU and RA samples with those obtained by Richardson et al (in press), who used a similar type of task with younger adult subjects, indicates that the DWLT is considerably easier than the task normed by Richardson (cf , Springer 1993) This suggests that the DWLT and DWLT30 would be appropriate for use with more severely impaired, adult, clinical populations, whereas the more demanding dichotic listening task normed by Ricardson et al (in press) might be preferable for use with less impaired populations Although no pilot studies have been performed to date, it seems likely that the DWLT task may also prove useful for assessing elderly patients, given its relatively simple and non-demanding format for younger adult populations

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